CONFORMAL COATINGS FOR PRINTED CIRCUIT ASSEMBLIES

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APRIL 15, 1962 TO JULY 15, 1962

U. S. ARMY SIGNAL SUPPLY AGENCY
STANDARDIZATION ENGINEERING DIVISION
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CONFORMAL COATINGS

FOR

PRINTED CIRCUIT ASSEMBLIES

Fourth Quarterly Report for the period of April 15, 1962 to July 15, 1962.

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Placed by: United States Army Signal Supply Agency
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Chicago Center
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Dept. of the Army Project Number: 5999-004

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CONFORMAL COATINGS FOR

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Objective:

Phase A: Evaluate commercially available conformal coating materials used as protective coatings on printed circuit boards in order to obtain data for the preparation of a three services coordinated military specification which will provide sufficient physical, mechanical and electrical properties to assure satisfactory performance of printed circuit assemblies over long storage periods and under high humidity conditions.

Phase B: Investigate a method of removing the coating from the board to permit replacement of parts when necessary without impairing the functional operations of the unit.

Phase C: Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on uncoated and coated boards as described in paragraphs 5.1.5 of MIL-STD-275A.

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PURPOSE

PHASE A The purpose of this project is to evaluate commercially available conformal coating materials used as protective coatings on printed circuit boards in order to obtain data for the preparation of a three services coordinated military specification which will provide sufficient physical, mechanical, and electrical properties to assure satisfactory performance of printed circuit assemblies over long storage periods and under high humidity conditions.

In this report, the stages are defined as follows:-

Stage A

Investigation of epoxy resin conformal coatings on XXXP, glass-epoxy and paper-epoxy copper clad laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Task 1 Two-part epoxy resin coating systems

Part 1 Characteristics of epoxy resin coatings studied.
Part 2 Curing Schedule.

Task 2 Test Panels used.

Task 3 Precoating Preparation of Surface

Part 1 Cleaning.
Part 2 Soldering.

Task 4 Method of Coating Application

Task 5 Physical and Electrical Properties of Epoxy Resin Coating Systems.

Part 1 Appearance and Adhesion.

Part 2 Thickness measurements.

Part 3 Dielectric Constant and Dissipation Factor of disc specimens.

Part 4 Dissipation Factor and Q-Factor of coated test panels.

Part 5 Dielectric Withstanding Voltage (initial).

Part 6 Thermal cycling.

Part 7 Dielectric Withstanding Voltage (after thermal cycling).

PURPOSE
(CONTINUED)

Part 8 Insulation resistance and appearance under moisture conditions.

Part 9 Dielectric Withstanding Voltage (after moisture test).

Part 10 Abrasion Resistance.

Part 11 Ruggedization.

Part 12 Flexibility.

Stage B.

Investigation of polyurethane resin conformal coatings on XXXP and glass-epoxy, copper-clad laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Tasks 1 - 5 The same as Stage A where application is feasible.

Stage C.

Investigation of Silicone-based polymer coatings on glass-epoxy and silicone-glass copper-clad laminate series specified in MIL-P-13949B.

Stage D.

Investigation of MIL-V-173 varnishes on glass-epoxy, XXXP and paper-epoxy laminates per MIL-P-13949B.

Tasks 1 - 5 The same as stage A where application is feasible.

PHASE B Investigate a method of removing the coating from the board to permit replacement of parts when necessary, without impairing the functional operations of the unit.

Stage A.

Investigation of chemical stripping of conformal coating as a method of repairing printed wiring assembly.

Stage B.

Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

PHASE C Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on coated and uncoated boards as described in paragraphs 5.1.5 of MIL-STD-275A.

ABSTRACT

Phase A

Stages C and D - Investigation of silicone and MFP varnish coatings on glass-epoxy, XXXP and paper-epoxy laminates specified in MIL-P-13949B.

Task 5 - Physical and Electrical Properties of Silicone and MFP varnish coating systems.

Part 5 - Initial Dielectric withstanding voltage.

All silicone and MFP varnish coated specimens passed the dielectric withstanding voltage tests specified in para. 4.7.8 of MIL-P-55110.

Part 6 - Thermal cycling.

When subjected to five cycles of the thermal cycling test specified in Method 102A of MIL-STD-202, all specimens passed without any evidence of cracking or deterioration of the coating or base materials.

Part 7 - Dielectric Withstanding voltage, after thermal cycling.

All silicone and MFP varnish coated specimens passed the dielectric withstanding voltage tests specified in para. 4.7.8 of MIL-P-55110.

Part 8 - Insulation Resistance, under moisture conditions.

When subjected to the humidity test specified in Method 106 of MIL-STD-202, all silicone and MFP varnish specimens passed the minimum resistance value of 1 x 10^8 ohms specified in SCL6225 after ten cycles of humidity.

ABSTRACT

Phase A (continued)

Part 9 - Dielectric Withstanding Voltage, after moisture resistance.

All silicone and MFP coated specimens passed the dielectric withstanding voltage tests specified in para. 4.7.8 of MIL-P-55110.

Phase B

Stage A - Investigation of chemical stripping of conformal coating as a method of repairing printed wiring assembly.

Twenty eight solvents that were recommended as strippers for epoxy and polyurethane coatings were evaluated. It was found that three of these solvents effectively removed or softened the coating within a fifteen minute period. It was also found that when a recoated test pattern, which was stripped with these solvents prior to recoating, was subjected to the ten day moisture test specified in Method 106A of MIL STD-202, there was no evidence of any great change in the insulation resistance value nor corrosion of the copper conductors.

Stage B - Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

Hot and "cool" soldering iron techniques were evaluated. It was found that a hot iron whose tip temperature is at 600°F. chars and redeposits the material on the circuitry. However, when a "cooler" iron, whose tip temperature is at 300° to 400°F, is used the resin softens which then can be scraped off easily. When this technique was evaluated on a re-coated test pattern, and subjected to a ten day humidity test described in Stage A, it was found that there was no evidence of any great change in the insulation resistance value nor any corrosion of the copper conductors.

ABSTRACT

Phase C

Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on coated and uncoated boards as described in para. 5.1.5 of MIL-STD-275A.

130 test patterns, shown in the Appendix page v, were fabricated and coated with epoxy and polyurethane coatings. A circuit capable of handling 50 watts was designed for each spacing and is shown in the Appendix, page vi. However, when the test patterns were tested at the altitude and the voltage ratings specified in Tables I to IV of para. 5.1.5 of MIL-STD-275, it was found that the uncoated and coated specimens were capable of withstanding 78 watts without evidence of deterioration of the base laminate or the coating. Breakdown voltage tests were performed on the coated and uncoated test patterns at various altitudes and these results are shown in the Appendix, page xii.

PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

A conference trip was made by A. Beccasio and L. Nero to the Signal Corps, Fort Monmouth, New Jersey on May 8 and 10, 1962 to discuss the progress of the program and also results obtained in Quarterly Report no. 3.

On June 4 and 5, 1962, Mr. A.Z. Orlowski of the Signal Corps visited our plant in Chicago, Illinois to discuss and review progress made in Phases B and C of the program.

FACTUAL DATA

PHASE A

Stages C and D - Investigation of silicone and MFP varnish on glass - epoxy, XXXP and paper - epoxy laminates specified in MIL-P-13949B.

Task 5 - Physical and Electrical Properties of silicone and MFP varnish coating systems.

Part 5 - Initial Dielectric withstanding voltage

All dielectric withstanding voltage tests were performed on a Motorola built - Breakdown tester TE-8359 with output from 0 to 3000 volts AC at 60 cps. The test specimens were electrified for one minute at 1000 volts at room temperature.

Part 6 - Thermal cycling

The silicone and MFP coated test patterns were subjected to five cycles of the temperature cycling test described in Method 102A, Cond. D of MIL-STD-202.

Part 7 - Dielectric Withstanding voltage, after thermal cycling

The procedure described in Part 5 of Task 5 was followed.

Part 8 - Insulation Resistance under moisture conditions

The silicone and MFP coated specimens were subjected to 10 cycles of humidity specified in Method 106 of MIL-STD-202. During the humidity cycling, 100 volts DC was applied continuously to each specimen. Insulation resistance measurements were taken initially, on a Keithley Instruments 610 megohm meter, and after the first, fourth, seventh and tenth cycles in accordance with Method 301 of MIL-STD-202. Prior to measurement, the test patterns were electrified at 500 volts for

15 seconds. Insulation resistance measurements were taken with the test specimens maintained at 25°C and 90-95% relative humidity. The insulation resistance data is presented in the Appendix, page vii.

Part 9 - Dielectric withstanding voltage, after moisture conditions

The procedure described in Part 5 of Task 5 was followed.

PHASE B

Stage A - Investigation of chemical stripping of conformal stripping of conformal coating as a method of repairing printed wiring assembly.

Twenty eight solvents and compounds that were recommended for use as strippers of epoxy and polyurethane coatings were evaluated as to the following parameters:-

(1) Corrosion effect on copper.

(2) Effectiveness as a stripper of epoxy and polyurethane coatings.

The procedure for determining these parameters is as follows:-

(1) Corrosion effect on copper.

1 inch x 3 inch strips of Type PP,PE,GE,GF and GB copper-clad laminates were dipped into the twenty eight solvents. Prior to dipping into the solvents, the copper surface was scrubbed with pumice to remove oxides and residues. The copper clad laminates were dipped for 15 minutes after which they were allowed to dry overnight. The laminates were then examined under the microscope for attack of copper as well as attack on the laminates.

(2) Effectiveness of stripping of epoxy and polyurethane coatings.

A few drops of the strippers were placed on coated epoxy and polyurethane specimens. After 15 and 30 minutes the coating was examined for attack.

The data from this investigation appears on the Appendix, p.x. In order to determine the effect of humidity o. chemical removal, the following procedure wa' used:

(1) Apply the tripper to the test pattern with an eye dropper and let stand for approximately fifteen minutes.

(2) Use the knife end of a soldering aid tool and gently scrape off the uplifted coating.

(3) Rinse the remaining stripper from the test pattern in cold running water using a soft hand brush on the board to ensure thorough removal.

(4) Dry test pattern using clean, filtered compressed air.

(5) In some of the test patterns, after the coating was removed the circuitry and surrounding laminate was sanded with a fine grade of emory paper to better the adhesion of the recoat coating.

(6) Recoat board to evaluate compatibility of coatings in the recoat operation, the following combinations were tested:

- (a) epoxy on epoxy
- (b) epoxy on polyurethane
- (c) polyurethane on epoxy
- (d) polyurethane on polyurethane
- (e) silicone on epoxy
- (f) silicone on polyurethane

NOTE: ALL TEST PATTERNS USED WERE COATED AT LEAST SIX MONTHS PRIOR TO EVALUATING REMOVAL TECHNIQUES. All recoated boards were allowed to stand at room temperature for seven days prior to subjecting them to the humidity test described in part 8 of Task 5. Insulation resistance measurements were also taken during this test using the same procedure described in part 8 of Task 5. This data is presented in the Appendix, page xvi.

Stage B - Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

The only technique investigated was the use of a soldering iron. In order to determine what tip temperature is necessary to effect complete removal of the coating, the following procedure was followed:

The temperature of the soldering iron tip was controlled by adjusting the input voltage with a powerstat or Variac. The tip temperature was measured with a Leeds and Northrup potentiometer to which an iron - constantin thermocouple was silver soldered to the tip of the soldering iron. The effectiveness of removal of the coating was evaluated from 100°F to 600°F in 50°F increments. The technique developed consists of holding the soldering iron at about 45° angle from the coated board and using it as a chisel to shave off the coating. This operation was repeated until all the coating was removed. The test pattern was then recoated, using the technique described in Stage A of Phase B. The recoated boards were then subjected to the same humidity test described also in part 8 of Task 5 of Phase A. The insulation resistance data is presented in the Appendix, page xvi and the effect of soldering iron temperature on the removal of the conformal coating is presented in the Appendix, page ix.

PHASE C

Evaluate, for possible upgrading purposes, allowable minimum spacings BETWEEN conductors on coated and uncoated boards as described in paragraph 5.1.5 of MIL-STD-275A.

A test pattern having five different spacings was developed. This test pattern had the following spacings. 0.022, 0.026, 0.062, 0.125 and 0.250 inches. A sketch of the test pattern is shown in the Appendix, page v. In order to more closely evaluate the maximum power requirements described in paragraph 5.1.5 of MIL-STD-275A, a test circuit, capable of handling 50 watts, was developed and is shown in the Appendix, page vi.

The approved epoxy and polyurethane coatings were coated on Type PP, PE, GF,GE, AND GB laminates. For each two coated specimens, two uncoated test patterns were run as co ' ols.

The coated and uncoated specimens were placed in an altitude chamber and the power applied to each spacing. Uncoated specimens were evaluated at 10,000 feet whereas the coated specimens were evaluated at 50,000 feet. Prior to applying the maximum voltages and power specified in Tables I thru IV of MIL-STD-275, insulation resistance measurements were taken. The voltage and power requirements for each spacing was applied to each specimen for 1/2 hour and then insulation resistance measurements were again taken. This test proved fruitless as it was discovered that the uncoated specimens were capable of handling 78 watts up to altitudes of 80,000 feet without any evidence of breakdown as shown by no change in the insulation resistance value.

The test patterns were then subjected to breakdown tests at 10,000; 25,000, 50,000 and 58,000 feet with the chamber temperature held at room ambient. The results of this test is shown in the Appendix, page xii.

CONCLUSION

PHASE A

Stages C and D-Investigation of silicone and MFP varnish coatings on glass-epoxy, XXXP and paper-epoxy laminates specified in MIL-P-13949B.

Task 5 - Physical and electrical properties of silicone and MFP varnish coating systems.

Parts 5,7 and 9 - Dielectric Withstanding Voltage

All silicone and MFP coated test patterns passed this test when 1000 volts AC was applied for one minute before and after thermal cycling and after moisture resistance tests.

Part 6 - Thermal cycling

All silicone and MFP coated test patterns passed five cycles of the thermal cycling test specified in MIL-STD-202 without any evidence of cracking or crazing of the coating.

Part 8 - Insulation resistance, under moisture conditions

All silicone and MFP coated test patterns passed the minimum resistance values of 1×10^8 ohms after ten cycles of humidity. When examined visually at the end of the test period, no evidence of corrosion or discoloration of the copper conductors was noticed.

Phase B

Stage A - Investigation of chemical stripping of conformal coating as a method of repairing printed wiring assembly.

Out of twenty eight solvents or strippers investigated, three were found to strip the epoxy and polyurethane coatings within a fifteen minute period.

Standard statistical analysis of the insulation resistance data reveals the following conclusions:

(1) Chemical and mechanical methods yielded equivalent results.

(2) The effect of the laminate and the base conformal coating were negligible.

(3) Epoxy and polyurethane coatings are compatible with one another. The only significant difference was that Epoxy F and Polyurethane GG were better than Epoxy I.

(4) Sanding of the repair area prior to recoat is better than no sanding. This indicates that better adhesion of the repair coating to the base laminate is obtained so that a better moisture barrier is provided.

(5) The insulation resistance value decreases as the number of humidity cycles increases.

Stage B Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

From the method evaluated, the following conclusions can be derived:

(1) Best removal was obtained when soldering iron temperature was 300°F to 375°F.

(2) Smoking of the coating occurred at temperatures between 450°F and 500°F.

(3) Conductor leads lifted when the soldering iron temperature was 500°F or higher.

When this technique was evaluated on coated test patterns which when recoated were subjected to ten days of humidity, statistical analysis of the insulation resistance data revealed the same conclusions stated in Stage A.

Phase C

Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on coated and uncoated boards as described in paragraph 5.1.5 of MIL-STD-275A.

Analysis of the data shown in the Appendix, Table IX, the following conclusions can be arrived at:

(1) Breakdown voltages of coated and uncoated boards decrease with increasing altitude.

(2) Breakdown voltage is independent of laminate type.

(3) No great differences in the breakdown voltages were noted between epoxy and polyurethane conformal coatings.

Recommendations for Phase C

(1) We recommend that paragraph 5.1.5 of MIL-STD-275A be changed to read, as follows: - ... up to and including 75 watts ... instead of ... up to and including 50 watts ...

PROGRAM FOR NEXT INTERVAL

(1) Begin Phase D.

(2) Study for possible use as conformal coatings compounds other than epoxies, polyurethanes and silicones.

(3) Begin study on the effect of humidity (long term) vs. thickness of conformal coating on electrical properties of the circuit.

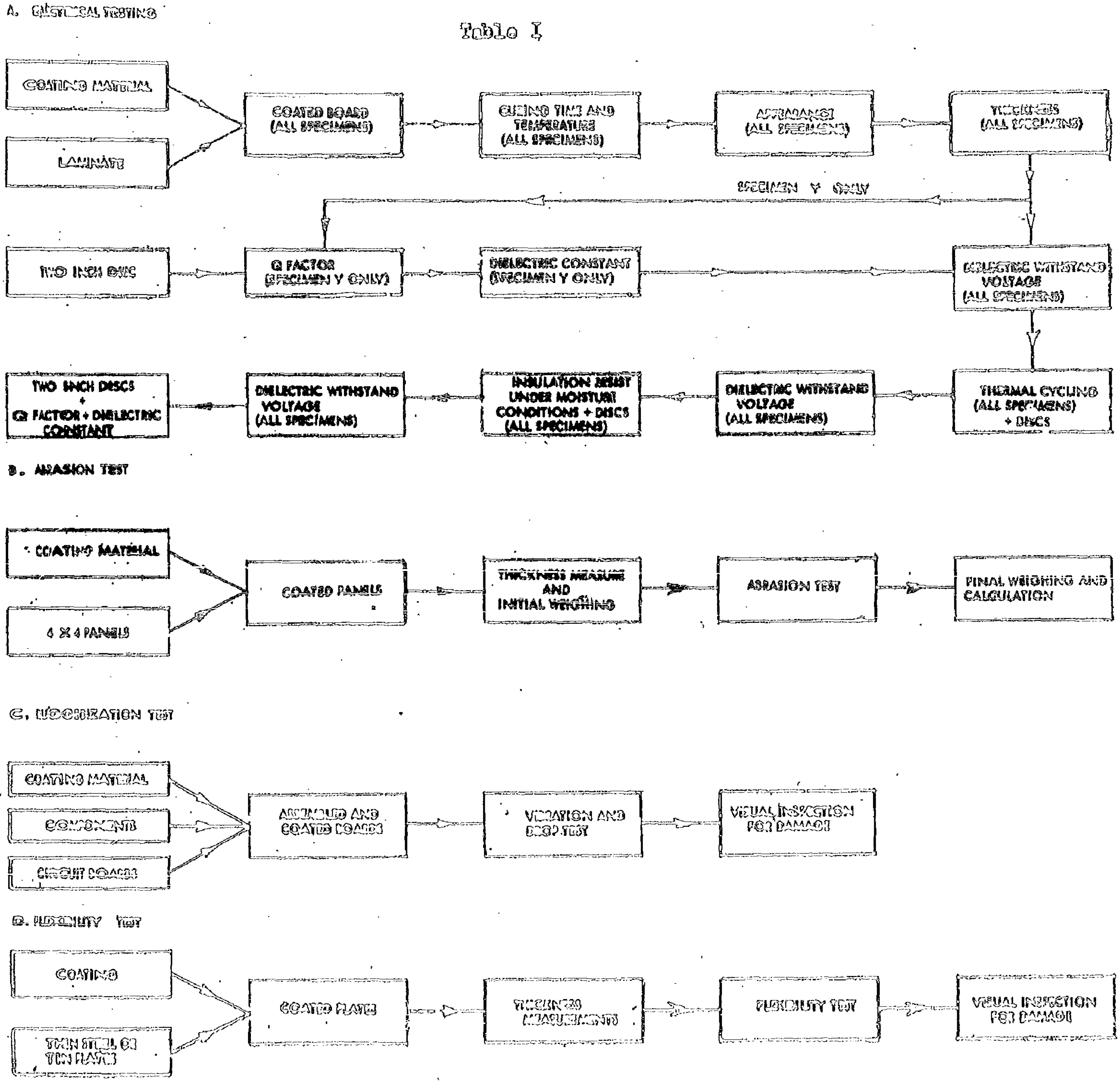
IDENTIFICATION OF KEY PERSONNEL

	TIME SPENT - HOURS
Mr. Anthony Beccasio Project Engineer	271
Mr. Leonard Nero Statistician and Chemist	356
Mr. Arthur Bethke Chemist	26
Mr. Ernesto Colon Technician	85
Mr. Anthony Miraglio Technician	68
Mr. Edgar Wolfgram Technician	8
TOTAL HOURS	814

A P P E N D I X

FLOW CHART FOR PHASE A TESTING

Table I

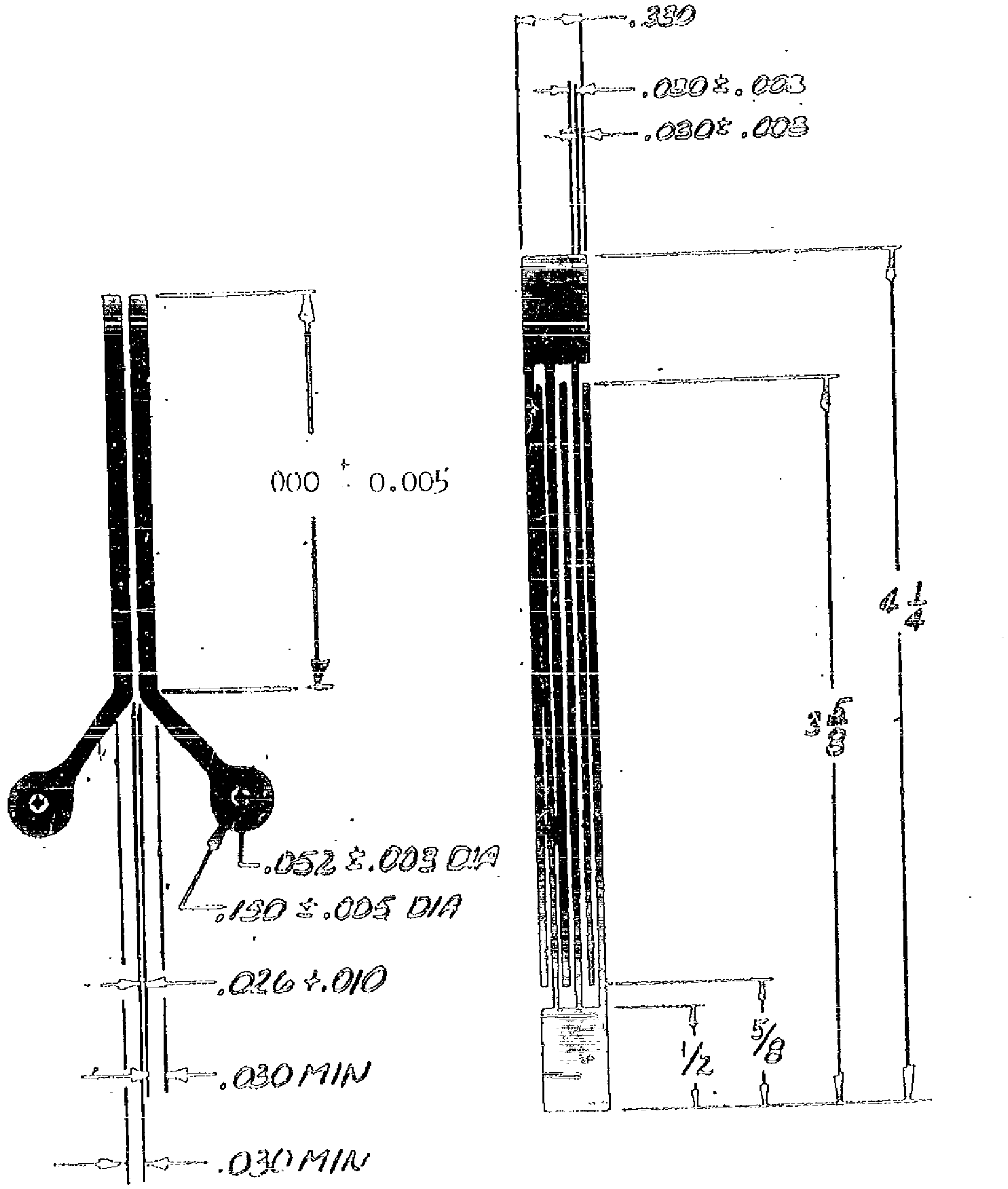


DRAWN BY A.J.D. AUG. [illegible]

TABLE II

COATING MANUFACTURERS

This table has been purposely omitted.



SPECIMEN X

SPECIMEN Y

TABLE III
TEST PANELS

TABLE IV

TEST PLAN FOR PHASE 2

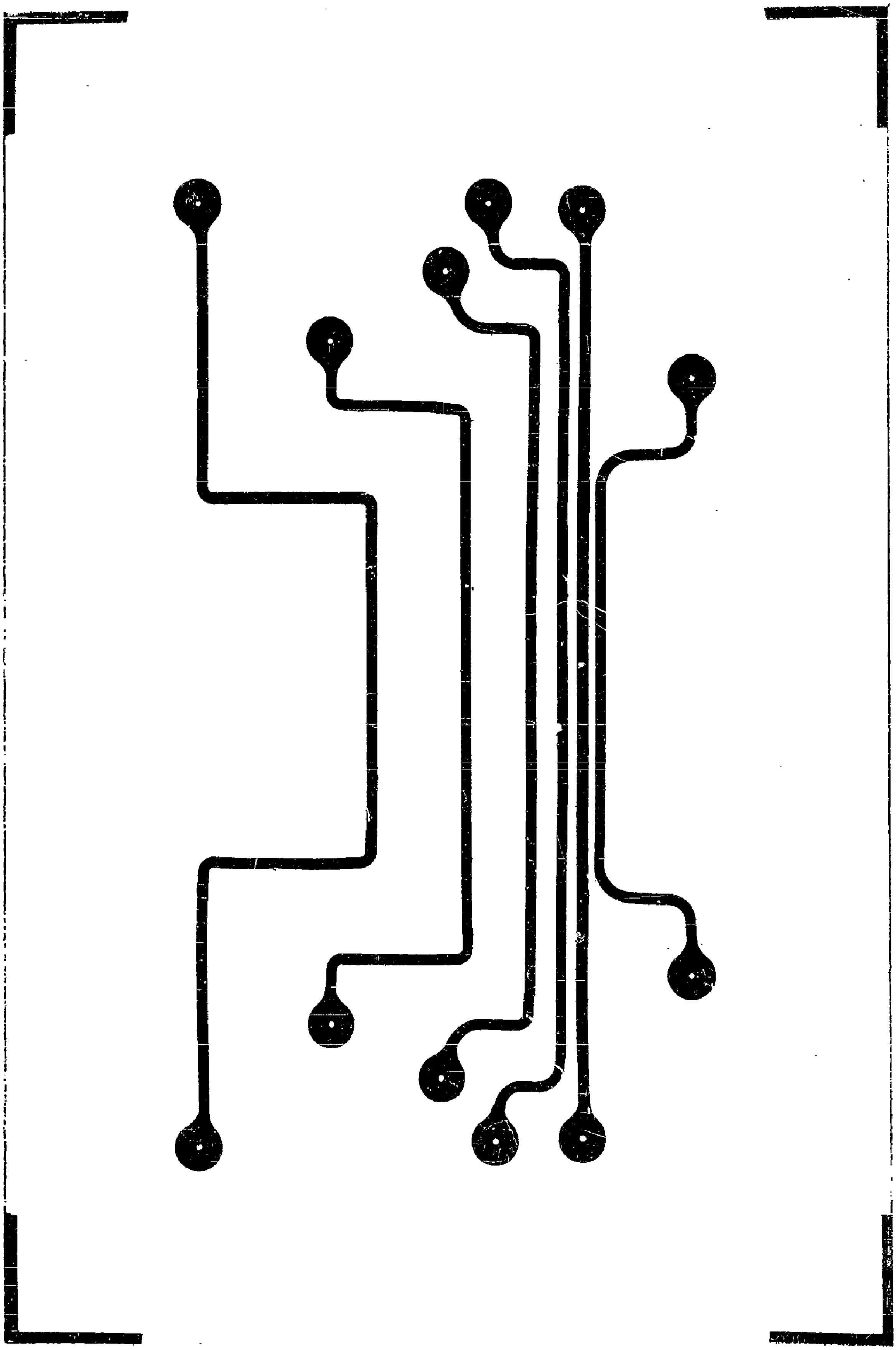


TABLE V CIRCUIT DIAGRAM FOR PHASE C

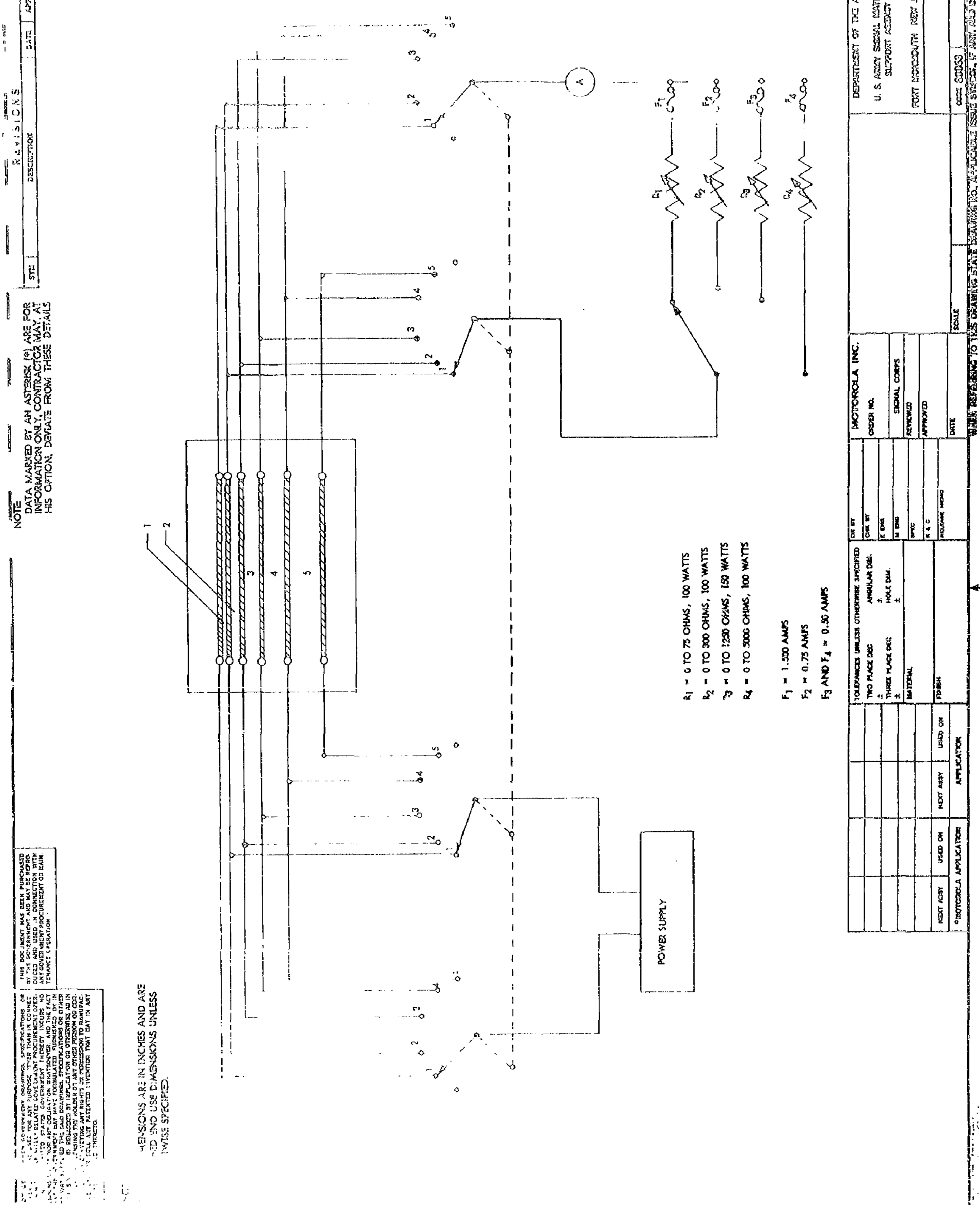


TABLE VI

INSULATION RESISTANCE MEASUREMENTS OF SILICONE AND MFP CONFORMAL COATINGS

Laminate and Sample No.	Pattern Number	Insulation Resistance, after (in ohms) initial	1st cycle	5th cycle	7th cycle	10th cycle	14th cycle
EXXXP MFP-1	1	2.0×10^{11}	4.0×10^{10}	2.0×10^{10}	1.0×10^{10}	4.0×10^{9}	
	2	1.5×10^{11}	4.0×10^{10}	2.0×10^{10}	1.0×10^{10}	3.0×10^{9}	
	3	2.0×10^{11}	4.0×10^{10}	2.0×10^{10}	1.0×10^{10}	3.0×10^{9}	
	control	1.5×10^{11}	1.0×10^{10}	8.0×10^{9}	4.0×10^{9}	2.0×10^{9}	
XXXP MFP-1	1	1.5×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	2	2.0×10^{11}	2.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	3	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	control	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
GF MFP-1	1	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	8.0×10^{10}	6.0×10^{10}	
	2	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	1.0×10^{11}	8.0×10^{10}	
	3	2.0×10^{11}	4.0×10^{11}	2.0×10^{11}	9.0×10^{10}	7.0×10^{10}	
	control	2.0×10^{11}	3.0×10^{11}	1.5×10^{11}	less than 10^{7} ohms ----		
GB MFP-1	1	2.0×10^{11}	3.0×10^{11}	2.0×10^{11}	6.0×10^{10}	2.0×10^{10}	
	2	2.0×10^{11}	3.5×10^{11}	2.0×10^{11}	6.0×10^{10}	2.0×10^{10}	
	3	2.0×10^{11}	3.0×10^{11}	2.0×10^{11}	6.0×10^{10}	4.0×10^{10}	
	control	2.0×10^{11}	1.0×10^{10}	less than 10^{7} ohms ----			
GE MFP-1	1	2.0×10^{11}	5.0×10^{11}	4.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	2	2.0×10^{11}	5.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	3	2.0×10^{11}	5.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	control	1.0×10^{11}	2.0×10^{11}	less than 10^{7} ohms ----			
XXXP MFP-2	1	1.5×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	2	2.0×10^{11}	3.0×10^{11}	2.0×10^{11}	1.5×10^{11}	2.0×10^{11}	
	3	2.0×10^{11}	3.0×10^{11}	2.0×10^{11}	1.5×10^{11}	1.5×10^{11}	
	control	2.0×10^{11}	5.0×10^{10}	less than 10^{7} ohms ----			
EXXXP MFP-2	1	2.0×10^{11}	4.0×10^{10}	2.0×10^{10}	1.0×10^{10}	4.0×10^{9}	
	2	2.0×10^{11}	5.0×10^{10}	2.0×10^{10}	1.0×10^{10}	3.0×10^{9}	
	3	2.0×10^{11}	5.0×10^{10}	2.0×10^{10}	1.0×10^{10}	3.0×10^{9}	
	control	2.0×10^{11}	2.0×10^{10}	8.0×10^{9}	3.0×10^{9}	2.0×10^{9}	
GF MFP-2	1	2.0×10^{11}	4.0×10^{11}	2.0×10^{11}	4.0×10^{10}	1.0×10^{10}	
	2	2.0×10^{11}	3.5×10^{11}	1.5×10^{11}	4.0×10^{10}	1.0×10^{10}	
	3	2.0×10^{11}	3.0×10^{11}	6.0×10^{10}	1.0×10^{10}	3.0×10^{7}	
	control	2.0×10^{11}	2.0×10^{7}	1.5×10^{7}	less than 10^{7} ohms ----		
GB MFP-2	1	2.0×10^{11}	3.0×10^{11}	2.0×10^{11}	1.0×10^{11}	9.0×10^{10}	
	2	2.0×10^{11}	1.0×10^{10}	2.0×10^{11}	1.0×10^{11}	8.0×10^{10}	
	3	2.0×10^{11}	3.0×10^{11}	1.5×10^{11}	1.0×10^{11}	7.0×10^{10}	
	control	2.0×10^{11}	2.0×10^{11}	1.0×10^{11}	1.0×10^{11}	3.0×10^{10}	
GE MFP-2	1	1.5×10^{11}	3.0×10^{11}	3.0×10^{11}	1.5×10^{11}	2.0×10^{11}	
	2	2.0×10^{11}	3.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	3	2.0×10^{11}	3.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	control	1.5×10^{11}	4.0×10^{10}	5.0×10^{10}	1.5×10^{11}	1.0×10^{11}	

TABLE VI (CONT)

Laminate and Sample No.	Pattern Number	Insulation Resistance, after (in ohms)					
		initial	1st cycle	5th cycle	7th cycle	10th cycle	14th cycle
GF silicone-1	1	2.0×10^{11}	3.0×10^{11}	2.5×10^{11}	1.5×10^{11}	8.0×10^{10}	
	2	2.0×10^{11}	3.0×10^{11}	2.5×10^{11}	1.5×10^{11}	8.0×10^{10}	
	3	2.0×10^{11}	3.0×10^{11}	2.5×10^{11}	1.5×10^{11}	1.0×10^{11}	
	control	2.0×10^{11}	2.5×10^{11}	1.5×10^{11}	1.0×10^{11}	less than 10^7	
GB silicone-1	1	2.0×10^{11}	3.0×10^{11}	2.5×10^{11}	1.5×10^{11}	1.0×10^{11}	
	2	2.0×10^{11}	3.0×10^{11}	2.5×10^{11}	1.5×10^{11}	1.0×10^{11}	
	3	2.0×10^{11}	3.0×10^{11}	2.5×10^{11}	1.5×10^{11}	5.0×10^{10}	
	control	1.0×10^{11}	5.0×10^{7}	2.0×10^{11}	1.0×10^{11}	5.0×10^{10}	
GE silicone-1	1	2.0×10^{11}	4.0×10^{11}	3.0×10^{11}	1.5×10^{11}	2.0×10^{11}	
	2	2.0×10^{11}	4.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	3	1.5×10^{11}	4.0×10^{11}	3.5×10^{11}	2.0×10^{11}	2.0×10^{11}	
	control	1.5×10^{11}	3.0×10^{11}	2.5×10^{11}	less than 10^7 ohms	-----	
GE silicone-2	1	1.5×10^{11}	4.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	2	1.5×10^{11}	4.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	3	1.5×10^{11}	4.0×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	
	control	1.5×10^{11}	3.0×10^{11}	2.5×10^{11}	2.0×10^{11}	1.5×10^{11}	
GF silicone-2	1	2.0×10^{11}	5.0×10^{11}	2.5×10^{11}	1.5×10^{11}	7.0×10^{10}	
	2	2.0×10^{11}	4.0×10^{11}	2.0×10^{11}	1.0×10^{11}	6.0×10^{10}	
	3	1.5×10^{11}	3.0×10^{11}	2.0×10^{11}	2.0×10^{11}	7.0×10^{10}	
	control	3.0×10^{9}	less than 10^7 ohms	-----	-----	-----	
GB silicone-2	1	2.0×10^{11}	4.0×10^{11}	1.0×10^{11}	8.0×10^{10}	4.0×10^{10}	
	2	2.0×10^{11}	3.0×10^{11}	1.5×10^{11}	8.0×10^{10}	4.0×10^{10}	
	3	2.0×10^{11}	5.0×10^{11}	2.0×10^{11}	8.0×10^{10}	7.0×10^{10}	
	control	2.0×10^{11}	1.5×10^{11}	7.0×10^{10}	5.0×10^{10}	3.0×10^{10}	

TABLE VII

EFFECT OF SOLDERING IRON TEMPERATURE VS. REMOVAL OF EPOXY CONFORMAL COATING

Temperature °F.	Equiv. millivolts	Comments on coating removal
100	1.94	no softening of coating
150	3.41	slight softening
200	4.91	slight softening
250	6.42	medium softening
300	7.94	softening- very easy removal
350	9.48	softening- very easy removal
400	11.03	softening- very easy removal
450	12.57	softening- very easy removal plus smoking and rupture of leads
500	14.12	softening- very easy removal plus smoking and lifting of leads.
550	15.65	softening- very easy removal plus smoking and lifting of leads.
600	17.18	softening- very easy removal plus smoking and lifting of leads.

TABLE IX EFFECT OF SOLVENTS ON COPPER-CLAD LAMINATES AND ON EPOXY AND POLYURETHANE COATINGS

CODE
(PP) XXXP --- X
(PE) EXXXP -- EX
(GE) G10 ----- E
(GB) G11 ----- B
GF ----- F
NE ------ No effect

Solvent	Corrosion 15' dip & air dry	Effect on Epoxy	Effect on Polyurethanes	Effect on Laminates Worst -- To --	Best
Acetone	O.K.	15' soft	15' soft	X F E EX	B
Solvent A	O.K.	NE	NE	NE	
Solvent B	Severe	30' soft	30' soft	X Rest	B NE
n-Butyl Acetate	O.K.	NE	NE	X Rest - NE	
Cellosolve Acetate	O.K.	NE	NE	X Rest - NE	
Solvent C	O.K.	30' soft	NE	X E F EX	B NE
Solvent D	Discolor	NE	15' lifted	X F E EX	B NE
Di Isobutyl Ketone	O.K.	NE	NE	NE	
Ethyl Acetate	O.K.	NE	NE	X F E EX	B NE
Solvent E	O.K.	30' soft	NE	X E EX F	B NE
Furfural	O.K.	30' soft	30' soft	X E F EX	B NE
Furfuryl Alcohol	O.K.	30' soft	3C lift	E X Rest - NE	
Solvent F	O.K.	NE	NE	NE	

TABLE IX (CONT.)

Solvent	Corrosion 15' dip & air dry	Effect on Epoxy	Effect on Polyurethanes	Effect on Laminates Worst -- To --	Best
Solvent G	O.K.	NE	NE	NE	
Solvent H	O.K.	NE	NE	NE	
Solvent I	O.K.	NE	NE	NE(GIO & X stained)	
Solvent J	O.K.	NE	5' lift	X F EX E	B NE
Solvent K	Coated copper	30' soft	5' lift	X EX E F	B NE
Solvent L	O.K.	30' soft	30' soft	X F E EX	B NE
Methyl Ethyl Ketone	O.K.	15' soft	15' soft	X F EX E	B
Methyl Iso-butyl Ketone	O.K.	NE	NE	X EX Rest - NE	
Solvent M	O.K.	NE	NE	X Rest - NE	
Solvent N	Discolor	15' soft	5' lift	X F E EX	
Solvent O	O.K.	30' soft	NE	X E Rest - NE	
Solvent P	O.K.	NE	NE	NE	
Tetrahydro-furfuryl Alcohol	O.K.	NE	NE	X E EX Rest - NE	
Solvent Q	Mild	15' lift	15' lift	X E F EX	B NE
Solvent R	Discolor	15' lift	15' lift	X EX F E	B NE

TABLE IX

BREAKDOWN VOLTAGES VS. ALTITUDE OF COATED AND UNCOATED SPECIMENS

Board type and sample	Gap spacing (inches)	Altitude - 10,000 ft.					
		Breakdown voltage (pattern 1)		Breakdown voltage (pattern 2)		Average breakdown voltage	
		coated	uncoated	coated	uncoated	coated	uncoated
GE	0.022	3.0 KV	1.35 KV	2.1 KV	1.0 KV	2.45 KV	1.17 KV
VR	0.026	2.0 KV	1.40 KV	2.1 KV	1.7 KV	2.05 KV	1.55 KV
GG	0.062	3.0 KV	2.05 KV	2.6 KV	2.4 KV	2.80 KV	2.20 KV
	0.125	With. 3 KV	3.00 KV	withstood	3KV - 1 min	~ 3.00 KV	~ 3.00 KV
	0.250	withstood 3	KV - 1 min.	----	----	----	----
GF	0.022	2.9 KV	1.5 KV	3.0 KV	1.6 KV	2.95 KV	1.55 KV
VR	0.026	2.4 KV	1.7 KV	2.9 KV	1.6 KV	2.65 KV	1.65 KV
GG	0.062	2.6 KV	2.1 KV	with. 3 KV	2.4 KV	~ 2.80 KV	2.25 KV
	0.125	with. 3 KV	3.0 KV	with. 3 KV	3.0 KV	3.00 KV	----
	0.250	withstood 3	KV - 1 min.	----	----	----	----
GB	0.022	1.9 KV	1.2 KV	2.5 KV	1.5 KV	2.2 KV	1.35 KV
Epoxy	0.026	1.7 KV	1.3 KV	2.2 KV	1.7 KV	1.95 KV	1.50 KV
I	0.062	2.6 KV	2.1 KV	with. 3 KV	2.4 KV	~ 2.80 KV	2.25 KV
	0.125	with 3 KV	3.0 KV	with. 3 KV	3.0 KV	----	3.00 KV
	0.250	withstood 3	KV - 1 min.	----	----	----	----
GF	0.022	3.0 KV	1.6 KV	3.0 KV	1.5 KV	3.00 KV	1.55 KV
Epoxy	0.026	3.0 KV	1.4 KV	2.9 KV	1.7 KV	2.95 KV	1.55 KV
I	0.062	2.9 KV	1.8 KV	3.0 KV	2.0 KV	2.95 KV	1.90 KV
	0.125	with. 3 KV	3.0 KV	with. 3 KV	3.0 KV	----	3.00 KV
	0.250	withstood 3	KV - 1 min.	----	----	----	----
GB	0.022	with. 3 KV	1.2 KV	with. 3 KV	1.4 KV	----	1.30 KV
VR	0.026	3.0 KV	1.5 KV	with. 3 KV	1.7 KV	~ 3.0 KV	1.60 KV
GG	0.062	with. 3 KV	1.9 KV	3.0 KV	2.2 KV	~ 3.0 KV	2.05 KV
	0.125	withstood 3	KV - 1min.	----	----	----	----
	0.250	withstood 3	KV - 1 min.	----	----	----	----
EXXXP	0.022	with. 3 KV	1.2 KV	with. 3 KV	1.2 KV	----	1.20 KV
VR	0.026	2.7 KV	1.6 KV	3.0 KV	1.7 KV	2.85 KV	1.65 KV
AA	0.062	2.3 KV	2.3 KV	3.0 KV	2.0 KV	2.65 KV	2.15 KV
	0.125	withstood 3	KV - 1 min.	----	----	----	----
	0.250	withstood 3	KV - 1 min.	----	----	----	----

TABLE IX (CONT.)

Board type and sample	Gap spacing (inches)	Altitude - 25,000 ft.					
		Breakdown voltage (pattern 1)		Breakdown voltage (pattern 2)		Average breakdown voltage	
		coated	uncoated	coated	uncoated	coated	uncoated
PP Poly GG	0.022	2.0 KV	1.3 KV	With. 3 KV	1.2 KV	~ 2.5 KV	1.25 KV
	0.026	2.4 KV	1.4 KV	1.2 KV	1.4 KV	1.8 KV	1.40 KV
	0.062	2.1 KV	1.8 KV	2.2 KV	1.6 KV	2.15 KV	1.70 KV
	0.125	2.4 KV	2.7 KV	2.6 KV	2.5 KV	2.50 KV	2.60 KV
	0.250	with. 3 KV	2.8 KV	with. 3 KV	2.5 KV	----	2.65 KV
PE Epoxy F	0.022	1.2 KV	1.3 KV	1.5 KV	1.2 KV	1.35 KV	1.25 KV
	0.026	1.5 KV	1.4 KV	1.6 KV	1.3 KV	1.55 KV	1.35 KV
	0.062	1.9 KV	1.8 KV	2.0 KV	1.8 KV	1.95 KV	1.80 KV
	0.125	2.9 KV	2.5 KV	2.5 KV	2.5 KV	2.70 KV	2.50 KV
	0.250	2.90 KV	2.7 KV	3.0 KV	3.0 KV	2.95 KV	2.85 KV
GE Poly AA	0.022	2.0 KV	1.3 KV	2.4 KV	1.3 KV	2.20 KV	1.30 KV
	0.026	2.2 KV	1.3 KV	2.0 KV	1.3 KV	2.10 KV	1.30 KV
	0.062	2.3 KV	1.9 KV	2.3 KV	1.8 KV	2.30 KV	1.85 KV
	0.125	3.0 KV	2.2 KV	2.9 KV	2.3 KV	2.95 KV	2.25 KV
	0.250	with. 3 KV	2.8 KV	with. 3 KV	2.8 KV	----	2.80 KV
GB Poly AA	0.022	3.0 KV	1.2 KV	with. 3 KV	1.1 KV	~ 3.0 KV	1.15 KV
	0.026	2.2 KV	1.3 KV	1.7 KV	1.2 KV	1.95 KV	1.25 KV
	0.062	2.6 KV	1.7 KV	2.6 KV	1.7 KV	2.60 KV	1.70 KV
	0.125	3.0 KV	2.3 KV	2.9 KV	2.4 KV	2.95 KV	2.35 KV
	0.250	3.0 KV	3.0 KV	with. 3 KV	3.0 KV	~ 3.00 KV	3.00 KV
GF Epoxy F	0.022	3.0 KV	1.3 KV	1.8 KV	1.1 KV	2.40 KV	1.20 KV
	0.026	2.2 KV	1.4 KV	1.4 KV	1.3 KV	1.80 KV	1.35 KV
	0.062	2.3 KV	1.4 KV	1.9 KV	1.5 KV	2.10 KV	1.45 KV
	0.125	2.6 KV	2.1 KV	2.4 KV	2.0 KV	2.50 KV	2.05 KV
	0.250	3.0 KV	2.3 KV	2.7 KV	2.4 KV	2.85 KV	2.35 KV

TABLE IX (CONT.)

Board type and sample	Gap spacing (inches)	Altitude - 50,000 ft.					
		Breakdown voltage (pattern 1)		Breakdown voltage (pattern 2)		Average breakdown voltage	
		coated	uncoated	coated	uncoated	coated	uncoated
PE Poly GG	0.022	1.4 KV	0.6 KV	1.5 KV	0.6 KV	1.50 KV	0.60 KV
	0.026	1.3 KV	0.8 KV	1.3 KV	0.7 KV	1.30 KV	0.75 KV
	0.062	1.3 KV	0.9 KV	1.3 KV	1.0 KV	1.30 KV	0.95 KV
	0.125	1.5 KV	1.4 KV	1.4 KV	1.4 KV	1.45 KV	1.40 KV
	0.250	1.7 KV	1.6 KV	1.8 KV	1.5 KV	1.75 KV	1.55 KV
GF Epoxy I	0.022	1.6 KV	0.7 KV	1.5 KV	0.7 KV	1.55 KV	0.70 KV
	0.026	1.1 KV	0.8 KV	1.2 KV	0.8 KV	1.15 KV	0.80 KV
	0.062	1.3 KV	0.9 KV	1.1 KV	0.9 KV	1.20 KV	0.90 KV
	0.125	1.3 KV	1.2 KV	1.3 KV	1.2 KV	1.30 KV	1.20 KV
	0.250	1.6 KV	1.2 KV	1.3 KV	1.3 KV	1.45 KV	1.25 KV
GE Epoxy I	0.022	1.1 KV	0.7 KV	1.4 KV	0.7 KV	1.25 KV	0.70 KV
	0.026	0.8 KV	0.9 KV	1.1 KV	0.7 KV	0.95 KV	0.80 KV
	0.062	1.0 KV	1.0 KV	1.3 KV	0.9 KV	1.15 KV	0.95 KV
	0.125	1.5 KV	1.3 KV	1.7 KV	1.4 KV	1.60 KV	1.35 KV
	0.250	1.7 KV	1.4 KV	1.8 KV	1.4 KV	1.75 KV	1.40 KV
GB Poly GG	0.022	1.5 KV	0.8 KV	1.6 KV	0.7 KV	1.55 KV	0.75 KV
	0.026	1.2 KV	0.8 KV	1.2 KV	0.7 KV	1.20 KV	0.75 KV
	0.062	1.2 KV	0.9 KV	0.8 KV	1.0 KV	1.00 KV	0.95 KV
	0.125	1.5 KV	1.2 KV	1.7 KV	1.2 KV	1.60 KV	1.20 KV
	0.250	1.7 KV	2.0 KV	1.7 KV	1.5 KV	1.70 KV	1.75 KV
PP Epoxy F	0.022	1.5 KV	0.6 KV	0.7 KV	0.8 KV	1.10 KV	0.70 KV
	0.026	1.0 KV	0.7 KV	0.8 KV	0.7 KV	0.90 KV	0.70 KV
	0.062	1.2 KV	0.9 KV	0.9 KV	0.9 KV	1.05 KV	0.90 KV
	0.125	1.7 KV	1.3 KV	1.4 KV	1.3 KV	1.55 KV	1.30 KV
	0.250	1.7 KV	1.5 KV	1.6 KV	1.5 KV	1.65 KV	1.50 KV

Board type and sample	Gap spacing (inches)	Altitude - 58,000 ft. Breakdown voltage (pattern 1)		Breakdown voltage (pattern 2)		Average breakdown voltage	
		coated	uncoated	coated	uncoated	coated	uncoated
PP Poly AA	0.022	1.3 KV	0.7 KV	1.3 KV	0.6 KV	1.30 KV	0.65 KV
	0.026	1.0 KV	0.6 KV	0.9 KV	0.6 KV	0.95 KV	0.60 KV
	0.062	1.0 KV	0.8 KV	1.0 KV	0.8 KV	1.00 KV	0.80 KV
	0.125	1.2 KV	1.0 KV	1.2 KV	1.1 KV	1.20 KV	1.05 KV
	0.250	1.4 KV	1.1 KV	1.5 KV	1.3 KV	1.45 KV	1.20 KV
GE Epoxy F	0.022	1.1 KV	0.7 KV	1.3 KV	0.6 KV	1.20 KV	0.65 KV
	0.026	0.7 KV	0.6 KV	1.0 KV	0.7 KV	0.85 KV	0.65 KV
	0.062	0.9 KV	0.8 KV	1.0 KV	0.8 KV	1.00 KV	0.80 KV
	0.125	1.2 KV	1.3KV	1.1 KV	1.1 KV	1.15 KV	1.20 KV
	0.250	1.3 KV	1.3 KV	1.6 KV	1.4 KV	1.45 KV	1.35 KV
GB Epoxy F	0.022	1.2 KV	0.7 KV	1.3 KV	0.5 KV	1.25 KV	0.60 KV
	0.026	1.0 KV	0.6 KV	1.0 KV	0.6 KV	1.00 KV	0.60 KV
	0.062	0.9 KV	0.9KV	0.9 KV	0.7 KV	0.90 KV	0.80 KV
	0.125	1.1 KV	1.0 KV	1.3 KV	1.0 KV	1.20 KV	1.00 KV
	0.250	1.3 KV	1.3 KV	1.3 KV	1.2 KV	1.30 KV	1.25 KV
PE Epoxy I	0.022	1.6 KV	0.6 KV	1.2 KV	0.6 KV	1.40 KV	0.60 KV
	0.026	1.2 KV	0.6 KV	1.0 KV	0.7 KV	1.10 KV	0.65 KV
	0.062	1.2 KV	0.8 KV	1.0 KV	0.9 KV	1.10 KV	0.85 KV
	0.125	1.4 KV	1.1 KV	1.3 KV	1.1 KV	1.35 KV	1.10 KV
	0.250	1.5 KV	1.2 KV	1.6 KV	1.3 KV	1.55 KV	1.25 KV
GF Poly AA	0.022	1.3 KV	0.6 KV	1.2 KV	0.6 KV	1.25 KV	9.60 KV
	0.026	1.0 KV	0.6 KV	1.0 KV	0.6 KV	1.00 KV	0.60 KV
	0.062	1.1 KV	0.8 KV	1.0 KV	0.7 KV	1.05 KV	0.75 KV
	0.125	1.2 KV	1.0 KV	1.1 KV	0.9 KV	1.15 KV	0.95 KV
	0.250	1.2 KV	1.1 KV	1.1 KV	1.1 KV	1.15 KV	1.10 KV

TABLE X

INSULATION RESISTANCE MEASUREMENTS OF RECOATED TEST PATTERNS

Laminate and Sample No.	Pattern Number	Insulation Resistance, after (in ohms) initial	1st cycle	5th cycle	7th cycle	10th cycle	14th cycle
GE Epoxy I on Epoxy I	mechanical	2.0×10^{9}	4.0×10^{11}	4.0×10^{11}	1.5×10^{11}	6.0×10^{9}	
	stripper A	2.0×10^{9}	4.0×10^{11}	3.5×10^{11}	1.5×10^{11}	7.0×10^{9}	
	stripper B	1.0×10^{9}	4.0×10^{11}	2.5×10^{11}	1.5×10^{11}	4.0×10^{9}	
	u control	2.0×10^{10}	2.0×10^{10}	6.0×10^{9}	1.5×10^{10}	1.5×10^{11}	
GE poly GG on poly GG	mechanical	2.0×10^{11}	2.0×10^{9}	2.5×10^{9}	1.0×10^{10}	2.0×10^{11}	
	chemical	1.5×10^{11}	3.0×10^{9}	2.0×10^{9}	1.0×10^{10}	2.0×10^{11}	
	c control	1.5×10^{11}	1.5×10^{9}	2.0×10^{9}	6.0×10^{9}	1.5×10^{11}	
	u control	6.0×10^{7}	3.0×10^{11}	2.5×10^{11}	1.0×10^{11}	1.5×10^{10}	
GF(sanded) silicone A on poly GG	stripper A	1.5×10^{11}	2.0×10^{11}	6.0×10^{10}	4.0×10^{10}	3.0×10^{10}	
	stripper B	1.5×10^{11}	2.0×10^{11}	6.0×10^{10}	4.0×10^{10}	3.0×10^{10}	
	mechanical	1.5×10^{11}	1.5×10^{11}	5.0×10^{10}	4.0×10^{10}	3.0×10^{10}	
	u control	1.0×10^{11}	6.0×10^{10}	2.0×10^{10}	1.0×10^{10}	8.0×10^{9}	
GE Epoxy I on Epoxy F	mechanical	1.0×10^{10}	3.0×10^{9}	1.0×10^{10}	9.0×10^{9}	5.0×10^{9}	
	chemical	3.0×10^{10}	5.0×10^{9}	2.0×10^{10}	1.0×10^{10}	7.0×10^{9}	
	c control	1.5×10^{11}	3.0×10^{10}	6.0×10^{10}	3.0×10^{10}	1.0×10^{10}	
	u control	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	less than 10^{7} ohms ----		
GE(sanded) silicone A on Epoxy F	stripper A	1.5×10^{11}	1.5×10^{11}	2.5×10^{11}	1.5×10^{11}	1.5×10^{11}	
	stripper B	1.5×10^{11}	2.5×10^{11}	2.5×10^{11}	1.5×10^{11}	1.5×10^{11}	
	mechanical	1.5×10^{11}	2.5×10^{11}	2.5×10^{11}	1.5×10^{11}	1.5×10^{11}	
	u control	1.5×10^{11}	1.5×10^{11}	1.0×10^{11}	1.0×10^{11}	1.5×10^{10}	
GF poly GG on Epoxy I	mechanical	1.5×10^{11}	3.0×10^{11}	2.0×10^{11}	1.0×10^{11}	8.0×10^{10}	
	chemical	1.5×10^{11}	2.0×10^{10}	1.5×10^{11}	7.0×10^{10}	6.0×10^{10}	
	c control	1.5×10^{11}	2.0×10^{11}	1.5×10^{11}	6.0×10^{10}	5.0×10^{10}	
	u control	1.0×10^{8}	4.0×10^{10}	less than 10^{7} ohms ----			
GE(sanded) poly GG on poly GG	stripper B	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	4.0×10^{10}	3.0×10^{10}	
	mechanical	1.0xx 10^{11}	1.0×10^{11}	7.0×10^{10}	3.0×10^{10}	2.0×10^{10}	
	stripper A	1.0×10^{11}	1.0×10^{11}	7.0×10^{10}	3.0×10^{10}	2.0×10^{10}	
	u control	7.0×10^{8}	6.0×10^{10}	5.0×10^{10}	2.0×10^{10}	1.0×10^{10}	
GB Poly GG on Epoxy F	c control	1.0×10^{11}	7.0×10^{10}	4.0×10^{10}	3.0×10^{10}	2.0×10^{10}	
	mechanical	1.0×10^{11}	1.5×10^{11}	4.0×10^{10}	2.0×10^{10}	1.5×10^{10}	
	chemical	1.0×10^{11}	6.0×10^{10}	4.0×10^{10}	2.0×10^{10}	1.5×10^{10}	
	u control	5.0×10^{7}	less than 10^{7}	1.0×10^{10}	3.0×10^{9}	3.0×10^{9}	
GB(sanded) silicone A on EPoxy I	stripper A	1.0×10^{11}	6.0×10^{10}	5.0×10^{10}	6.0×10^{10}	5.0×10^{10}	
	stripper B	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	3.0×10^{10}	2.0×10^{10}	
	mechanical	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	2.0×10^{10}	1.0×10^{10}	
	u control	1.0×10^{11}	4.0×10^{10}	3.0×10^{10}	1.0×10^{10}	6.0×10^{9}	
GB Epoxy F on Poly GG	c control	2.0×10^{11}	2.0×10^{11}	1.5×10^{11}	6.0×10^{10}	4.0×10^{10}	
	mechanical	2.0×10^{11}	2.0×10^{11}	1.5×10^{11}	4.0×10^{10}	2.0×10^{10}	
	chemical	2.0×10^{11}	1.5×10^{11}	1.0×10^{11}	2.0×10^{10}	1.0×10^{10}	
	u control	5.0×10^{10}	1.0×10^{10}	1.0×10^{7}	less than 10^{7} ohms ----		

NOTE: u control = uncoated control c control = coated control

TABLE X (CONT.)

Laminate and Sample No.	Pattern Number	Insulation Resistance, after (in ohms): initial	1st cycle	5th cycle	7th cycle	10th cycle	14th cycle
GF Epoxy F on Epoxy F	mechanical	1.0×10^{11}	7.0×10^{9}	1.0×10^{10}	4.0×10^{9}	5.0×10^{9}	
	stripper A	1.0×10^{11}	7.0×10^{9}	1.0×10^{10}	4.0×10^{9}	5.0×10^{9}	
	stripper B	7.0×10^{10}	6.0×10^{9}	1.0×10^{10}	4.0×10^{9}	4.0×10^{9}	
	u control	1.0×10^{11}	4.0×10^{9}	7.0×10^{9}	3.0×10^{9}	1.0×10^{9}	
GE Epoxy F on Epoxy I	c control	3.0×10^{11}	1.5×10^{11}	1.0×10^{11}	6.0×10^{10}	6.0×10^{10}	
	mechanical	3.0×10^{11}	7.0×10^{10}	4.0×10^{10}	3.0×10^{10}	2.0×10^{10}	
	chemical	3.0×10^{11}	1.0×10^{11}	1.0×10^{11}	4.0×10^{10}	3.0×10^{10}	
	u control	3.0×10^{11}	1.5×10^{11}	1.0×10^{11}	3.0×10^{10}	1.5×10^{10}	
GF Epoxy I on Epoxy I	stripper B	3.0×10^{9}	1.5×10^{9}	1.5×10^{9}	2.0×10^{9}	3.0×10^{9}	
	mechanical	4.0×10^{9}	2.0×10^{9}	1.5×10^{9}	2.0×10^{9}	2.0×10^{9}	
	stripper A	1.5×10^{9}	1.0×10^{9}	1.0×10^{9}	2.0×10^{9}	2.0×10^{9}	
	u control	1.5×10^{11}	1.0×10^{10}	7.0×10^{9}	5.0×10^{9}	2.0×10^{7}	
GB Epoxy I on Epoxy I	chemical	5.0×10^{10}	6.0×10^{9}	1.0×10^{10}	1.0×10^{10}	1.0×10^{10}	
	c control	3.0×10^{10}	1.0×10^{10}	1.5×10^{10}	1.0×10^{10}	1.0×10^{10}	
	mechanical	4.0×10^{10}	5.0×10^{9}	1.0×10^{10}	1.0×10^{10}	7.0×10^{9}	
	u control	1.5×10^{11}	5.0×10^{10}	4.0×10^{10}	less than 10^{7} ohms	----	
GB(sanded) Epoxy F on Epoxy F	stripper B	1.5×10^{10}	1.0×10^{11}	8.0×10^{10}	3.0×10^{10}	2.0×10^{10}	
	mechanical	2.0×10^{11}	1.5×10^{11}	1.0×10^{11}	4.0×10^{10}	3.0×10^{10}	
	stripper A	6.0×10^{10}	8.0×10^{10}	6.0×10^{10}	3.0×10^{10}	2.0×10^{10}	
	u control	2.0×10^{10}	l. than 10^{7}	1.0×10^{10}	8.0×10^{9}	5.0×10^{9}	
GF Epoxy I on Poly GG	chemical	2.5×10^{11}	5.0×10^{9}	4.0×10^{9}	4.0×10^{9}	4.0×10^{9}	
	c control	3.0×10^{11}	2.0×10^{10}	2.0×10^{10}	8.0×10^{9}	8.0×10^{9}	
	mechanical	3.0×10^{11}	1.0×10^{10}	8.0×10^{9}	6.0×10^{9}	5.0×10^{9}	
	u control	8.0×10^{8}	5.0×10^{7}	4.0×10^{7}	4.0×10^{7}	3.0×10^{7}	
GF Epoxy F on Epoxy F	chemical	6.0×10^{11}	1.0×10^{11}	1.0×10^{11}	7.0×10^{10}	6.0×10^{10}	
	c control	6.0×10^{11}	1.0×10^{11}	1.0×10^{11}	6.0×10^{10}	4.0×10^{10}	
	mechanical	5.0×10^{11}	1.5×10^{11}	1.5×10^{11}	7.0×10^{10}	5.0×10^{10}	
	u control	3.0×10^{8}	less than 10^{7} ohms	----	----	----	
GB Poly GG on Poly GG	mechanical	3.0×10^{11}	2.0×10^{10}	2.0×10^{10}	1.0×10^{10}	7.0×10^{9}	
	stripper A	3.0×10^{11}	2.0×10^{10}	2.0×10^{10}	1.0×10^{10}	6.0×10^{9}	
	stripper B	3.0×10^{11}	2.0×10^{10}	2.0×10^{10}	1.0×10^{10}	5.0×10^{9}	
	u control	3.0×10^{11}	l. than 10^{7}	7.0×10^{9}	5.0×10^{9}	3.0×10^{9}	

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